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FIRE RESISTANCE OF WOOD-STUD PARTITIONS FILLED WITH MINERAL WOOL

Several wood-framed partitions with the space between the studs and the facings filled with mineral wool have been included in a current series of fire tests in an effort to increase the fire resistance without change in the material or thickness of the facings. The constructions were built into movable frames and, for the fire test, were placed to form one wall of the furnace chamber. The tests were conducted in substantial accord with specifications developed under the auspices of several national technical societies and this Bureau (see American Standards Association Standard A-2-1934, and American Society for Testing Materials Standard C19-33).

Most of the partitions were tested under load in fire-endurance tests. Fire and hose-stream tests were conducted with constructions that withstood the fire-endurance test for 1 hour or more, and they were found to pass the requirements in this respect.

A summary of the results is given in the table, in which the fire-resistance periods are given for 1/4 hour intervals. For the bearing classification the results are based on ability to sustain for the given period under the fire exposure a design load, taken as 358 lb./in.² of net area of wood studs, prevent the occurrence of an average temperature rise on the side not exposed to fire of 250° F. or a rise at any point of 325° F., passage of flame, or ignition of cotton waste placed against the unexposed side. For the nonbearing classification all but the first of these criteria are applied.

¹ Published with approval of the Director of the Budget.

Results of fire tests of wood-stud partitions filled with mineral wool

* Material	Facings		Filling		Fire-endurance period	
	Thickness of plaster or board	Plaster mix	Form	Density	Bearing	Non-bearing
T & G 3-in. wood ceiling boards	In.			Lb./in. ³	Hr.	Hr.
Do.	1/4		Bulk, tamped	6.9	1/4	1/4
Do.	1/4		Bulk, loose	2.7	1/4	1/4
Do.	1/4		Bulk, hand-packed	2.6	1/2	1/2
Wood lath, lime plaster	1/2 { 1:5		Pellets, blown in	2.2		3/4
Gypsum board	1/2 { 1:7 1/2		Bats, not nailed	0.6 to 1.2	1/4	1
Do.	1/2 { 1:7 1/2		Bats, nailed	.6 to 1.2	1	1
Wood lath, gypsum plaster	1/4 { 1:2		Bats, not nailed	1.0 to 1.3	1	1
Do.	1/4 { 1:3		Bats, nailed	1.0 to 1.3	1	1
Metal lath, gypsum plaster	1/4 { 1:2		Bats, 2/3 nailed	1.0 to 1.3	1 1/4	1 1/4
Do.	1/4 { 1:1		do	1.0 to 1.3	1 1/2	1 1/2

In the first two tests listed, the loose rock wool was dropped into the stud space in a height of 4 ft and tamped with a sash weight in the case of the first test, and lightly packed with a stick for the second. Both failed through ignition of boards on the unexposed side at points where there were voids in the fill, the results differing little from those obtained with a similar unfilled partition. In the third test the fill was placed progressively as the facing was applied, resulting in a fill of more uniform density.

For the partition faced with lime plaster on wood lath, the fill was placed by pneumatic means after the partition was built and aged, the equipment used being typical of those applied in placing wall and attic insulations. The failure in this case was also apparently at a void or sparsely filled location in the fill. The partition, however, withstood the test for 16 min longer than a similar unfilled partition. Some further tests with wood-lath and plaster partitions with mineral-wool fill in bat form are in progress.

The rock, slag, and glass-wool bats applied as fill in the remaining tests were of the usual wall-thick types used for house insulation, with waterproofed paper on one side. They were 15 in. wide and 23 to 48 in. long, and were placed against one facing for the full height of the partition before the other facing was applied. Where secured by nailing, 8d finishing nails were driven on 12-in. centers through both ends of the bats into the middle of the sides of the studs. The densities given apply for the nominal area of the bats. As

compressed into the stud space the density would be about 10 percent higher, or equivalent to about 2.2 lb/ft³ for glass wool and 3.6 to 4.7 lb/ft³ for rock and slag wool.

The filling increased the fire resistance of the construction with the 1/2-in. gypsum board facing by 10 to 20 min, for that of gypsum plaster on wood lath by 25 to 30 min, and for those of gypsum plaster on metal lath by about 30 min. The proportions given in the table for the plaster mix are in terms of weight of gypsum plaster or dry hydrated lime to dry weight of sand. Where two ratios are given, the first is for the scratch coat and the other for the brown coat. The Potomac River sand used has a high content of quartz and chert. Where a white finish was applied, its thickness is included in the given thickness of facing.

The tests indicate that the filling of wood-stud partitions results in a substantial increase in fire resistance. The filling apparently retards the transmission of heat to the unexposed facing and decreases the rate of burning of the wood supports. The results indicate that care is needed to obtain a fill without voids. Apparently this condition is more often attained with fills in bat form placed before the last facing is applied than with fills placed after both facings are in place. The former method also affords opportunity for inspection. However, even with this type of construction care must be exercised if results comparable to the ones given here are to be obtained. The truth of this is brought out in cases where the facing on the side exposed to fire dis-

integrates or falls off relatively early in the test. Then, if the filling has been nailed in place, or held by equivalent means, added fire resistance is obtained. This is true to a less extent even if the facing does not fall off.

EFFLORESCENCE OF BRICKS

It is known that efflorescence on brick masonry may originate from the bricks or mortar, or both. It is also known that the soluble salts in bricks may originate from the raw materials (clay or shale), water, or from kiln gases. Observations in various communities in the United States show that in some the walls are practically free from observable efflorescence, while in others much is visible. On the assumption that some of these differences are related to differences in bricks, a statistical study was made of data accumulated in 1930 as part of a survey of properties of building brick produced in the United States. The data obtained included liability to efflorescence as measured by the 5-day wick test (J. Research NBS 19, 105; July 1937 RP1015), strength, water absorption, saturation coefficient (ratio of absorption by cold immersion to absorption by boiling), kind of raw material (clay, shale, or fire clay), method of forming (dry press, soft mud, side cut, and end cut), rating by manufacturers as to degree of firing ("hard" or "salmon"), and geographical location. A study of 638 samples from 219 manufacturers gave the following conclusions:

1. Liability to efflorescence is less for hard-fired brick than for under-fired brick if strength, absorption, and saturation coefficient are considered as measures of degree of firing.

2. No significant difference in tendency to efflorescence is found when bricks made from different raw materials, clay, shale, and fire clay, are compared.

3. No effect of method of forming (dry press, soft mud, side cut, and end cut) on tendency to efflorescence was observed.

4. The weighted distribution of the data for 638 samples from 219 plants is as follows: 85.0 percent less than "moderate", 10.9 percent "moderate", and 4.1 percent exceeding "moderate", on the scale for tendency to efflorescence as measured by the 5-day wick test.

5. The corresponding weighted values for the samples classified by the manufacturers as "hard" (94.1 percent of total) are 86.0 percent less than "moderate", 10.4 percent "moderate", and 3.6 percent greater than "moderate."

6. The weighted distributions for the samples classified by the manufacturers as "salmon" (5.9 percent of the total) are 67.8 percent less than "moderate", 19.0 percent "moderate", and 13.2 percent exceeding "moderate."

MEASUREMENT OF CAPILLARY FORCES IN POROUS MATERIALS

The capillary suction of porous materials, particularly those used in masonry construction, is of practical interest since it is largely responsible for the transmission of moisture from the exterior surface to the interior of the building. It is also possible that the capillary forces bear some relation to the resistance of masonry materials to certain destructive forces, such as frost action or the concentration of water-soluble salts giving rise to efflorescence.

Few measurements of capillary forces in masonry materials have been made. One method consists in sealing a tube into the specimen and connecting it to a mercury U-tube after which the specimen is immersed in water. As absorption proceeds the air on the interior of the specimen is compressed until the capillary forces are balanced by the mercury column. Another method consists in sealing the top of a vessel with a specimen of the porous material, while the bottom of the vessel is connected to an inverted U-tube, the free end of which dips in mercury. When the vessel and the tube, down to the mercury level, are entirely filled with water, the specimen immediately begins to absorb and transmit moisture as evaporation proceeds from the upper surface. The mercury rises in the tube until the capillary suction is balanced and the height of the mercury indicates the desired reading. With both of these methods the results obtained are only the capillary forces existing in the coarsest pores of the specimens. When the mercury reaches its maximum height it immediately recedes because of the removal of water from the larger pores. Hence, close observation is required in order to obtain the maximum reading.

In order to obtain measurements of the capillary suction existing in the finer pores of masonry materials, a new method has been devised which overcomes the objectionable feature of close personal observation and is also believed to obtain results which approximate the forces existing in the fine pores. This may be described as a compression method somewhat similar to the first except that the specimen is enclosed in a tight-fitting vessel, the top of which is connected to a mercury

U-tube, while the bottom of the vessel is sealed with a material of high capillary properties. By this method a mercury column rises as long as absorption continues and does not drop back when the maximum value is obtained. For the accessory porous material one may use plaster of paris or a mixture of litharge and glycerine, but a limestone of high capillary properties has been found more satisfactory. Of course, it is necessary to have intimate contact between the specimen and the accessory porous material so that water may pass freely from one to the other. By using this method some rather high capillary measurements have been obtained on porous materials which show very low values with the first two methods described. The limitations are that the values for the fine pores of the specimen can be obtained only up to the maximum limit of the coarsest pores in the accessory material.

FORMATION OF HYDRATED CALCIUM SILICATES AT ELEVATED TEMPERATURES AND PRESSURES

Although portland cement is predominantly a mixture of calcium silicates, the end products of the hydration of these compounds after setting have never been identified. The reason for this lies in the fact that these products are amorphous or microcrystalline when formed at ordinary temperatures, and crystallize with extreme slowness. However, crystallization is greatly accelerated by autoclave treatment, such as has recently been employed in the partial prehydration of portland cement and in the autoclave testing of neat-cement specimens. In the manufacture of sand-lime brick also, combination of lime and silica with water and incipient crystallization probably occur during autoclave treatment.

Possible analogues of such products exist in nature as crystalline calcium hydrosilicates, a group of rare but widely distributed minerals commonly found in contact zones of limestone and silicates and evidently formed by hydrothermal processes.

To obtain further information on the hydrated calcium silicates, an investigation from two angles was undertaken by E. P. Flint, Lansing S. Wells, and Howard F. McMurtrie. First, a study was made of the natural minerals to ascertain which of these are actually distinct species, and, second, the synthesis of some of the minerals and a

determination of the range of temperatures over which they are stable were attempted.

Comparison X-ray diffraction patterns of as many of the minerals as could be obtained showed the following to be distinct compounds: Okenite, $\text{Ca}_2\text{SiO}_5\cdot\text{H}_2\text{O}$; gyrolite, $2\text{CaO}\cdot3\text{SiO}_2\cdot2\text{H}_2\text{O}$; crestmoreite, $2\text{CaO}\cdot2\text{SiO}_2\cdot3\text{H}_2\text{O}$; xonotlite, $5\text{CaO}\cdot5\text{SiO}_2\cdot\text{H}_2\text{O}$; afwiliite, $3\text{CaO}\cdot2\text{SiO}_2\cdot3\text{H}_2\text{O}$; foshagite, $5\text{CaO}\cdot3\text{SiO}_2\cdot3\text{H}_2\text{O}$; and hillebrandite, $2\text{CaO}\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$. Centralitasite, $4\text{CaO}\cdot7\text{SiO}_2\cdot5\text{H}_2\text{O}$, and truscottite, $4(\text{Ca},\text{Mg})\cdot7\text{SiO}_2\cdot5\text{H}_2\text{O}$, appear to be impure forms of gyrolite. Riversideite, $2\text{CaO}\cdot2\text{SiO}_2\cdot\text{H}_2\text{O}$, does not seem to be a distinct mineral and is probably the same compound as crestmoreite.

Using as starting materials the anhydrous calcium silicates, amorphous hydrates, and glasses, preparations having X-ray patterns identical with those of gyrolite, xonotlite, and foshagite were obtained by hydrothermal treatment. Other products were cristobalite, wollastonite, pseudowollastonite, a low temperature form of anhydrous tricalcium disilicate, $4\text{CaO}\cdot5\text{SiO}_2\cdot5\text{H}_2\text{O}$, $\text{CaO}\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$, $10\text{CaO}\cdot5\text{SiO}_2\cdot6\text{H}_2\text{O}$, and $3\text{CaO}\cdot\text{SiO}_2\cdot2\text{H}_2\text{O}$.

At room temperature prolonged treatment of beta-dicalcium silicate and tricalcium silicate with water resulted in the formation of crystalline products which gave distinctive X-ray patterns.

RP1147 in the November Journal of Research will give the complete report of this investigation.

FIBER INSULATING LATH AS A PLASTER BASE

Among the modern building materials which appeal to many for house construction are the numerous types of wall, insulating, and plaster boards.

An investigation of the properties of these boards, with special reference to the suitability of fiber insulating lath as a plaster base, was completed recently at the Bureau, and a report on the work, Building Materials and Structures, BMS3, has just been released.

Such properties as density, strength (flexural and tensile), and linear changes accompanying changes in relative humidity and wetting and drying were studied. The boards were mounted on steel frames so that the extent of buckling resulting from changes in relative humidity could be measured. Methods of successful application of plaster on insulating lath were ascertained by experiments in which the

thickness, sand content, strength, and time of set of the plasters were varied independently.

The following types of boards were investigated: Eight fiber insulating, one plywood, two gypsum, one cement-asbestos, and one compressed fiber.

The weight of the fiber insulating boards (1/2 inch thick) ranged from 699 to 1,143 lb per 1,000 sq ft when measured at 65-percent relative humidity. The average flexural strengths of these boards at 80- and 100-percent relative humidity were about 20 and 50 percent lower, respectively, than at 40 percent.

The expansions which accompanied a change in the relative humidity of the air from 25 to 90 percent ranged from about 0.07 percent for the gypsum boards and cement-asbestos board to about 0.47 percent for some of the fiber insulating boards, the range of the latter type being about 0.26 to 0.47 percent. When the boards were kept at 100-percent relative humidity, or in water, the expansions were from 25 to 95 percent greater than those obtained at 90-percent relative humidity. Painting the boards materially decreased the rate of expansion, but did not eliminate it.

Boards attached rigidly along their edges to steel frames gave greater buckling (rise in hundredths of an inch, across a 16-inch span) than when the boards were less firmly attached. When firmly attached along the outside, the buckling of the boards ranged from 0.05 inch for the gypsum wall board to 0.54 inch for one of the fiber insulating boards when the relative humidity was increased from 35 to 90 percent.

It was found that weak, oversanded plasters applied to the insulating lath were very unsatisfactory even when quick-setting and 5/8 inch thick.

Strong, quick-setting plasters 5/8 inch thick were satisfactory, but when the thickness was 3/8 inch, cracks developed in some instances along the horizontal joints after the panels had been dried.

Copies of this report are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

RECORDS OF PRESENT CIVILIZATION PRESERVED IN "TIME CAPSULE"

Members of the Bureau's staff recently assisted in a most unusual venture, that of preparing a message for the civilization of the future, to be opened 5,000 years hence. The message is in the form of an 800-pound

Cupaloy "Time Capsule" which was deposited 50 feet below the surface of the New York World's Fair grounds by the Westinghouse Electric and Manufacturing Co., on September 23, 1938, with instructions that it is not to be opened before the year 6938. The capsule has sealed within it, in an atmosphere of nitrogen, records and articles portraying a cross section of our present-day civilization. Microfilm made it possible to pack a voluminous collection of records in a very small space, the four reels of film covering more than 100 volumes showing the scientific, engineering, industrial, social, religious, and philosophical achievements of our age. A "Book of Record of the Time Capsule," made to survive 5,000 years, was designed and published for the occasion, and copies will be deposited in various libraries. It is an example of the finest modern craftsmanship, set in Goudy type, printed on permanent record paper, bound in royal-blue buckram, and stamped in genuine gold. The book contains a message to posterity; a description of the contents of the capsule; detailed instructions for finding and raising the capsule; and a "Key to English" by John P. Harrington of the Smithsonian Institution. One copy was enclosed within the capsule, and other copies are to be preserved in libraries and other depositories throughout the world.

The paper used in the "Book of Record," the microfilm, the film cans, and the paper used to wrap separately the articles placed in the capsule were made in accordance with specifications furnished by the Bureau, which was also consulted on many other details. C. G. Weber of the Bureau's paper section was one of the three official witnesses of the packing and sealing of the capsule.

EFFECT OF FILLING AND SIZING MATERIALS ON STABILITY OF BOOK PAPERS

During the past 4 years the influence of composition and manufacturing processes on the stability of fine printing, or "book" paper, has been studied at the Bureau, and a report on the pulps commonly used for such paper has been published. A more recent study reported in the Journal of Research for November (RP1149 by Merle B. Shaw and Martin J. O'Leary) gives special consideration to the effect of filling and sizing materials introduced in manufacture. The investigation was made primarily to obtain information which

will assist in the classification of book papers according to their relative permanence, and the findings will serve as a guide in buying, particularly if the paper is to be used for the preservation of valuable records.

Fillers are not added to book paper to adulterate it, but to improve the printing quality of the sheet. They fill the interfiber spaces, decrease the harshness of the fiber, produce a more even-surfaced sheet, and increase opacity, or resistance to "show-through," of printing.

The kinds of fillers on the market have increased considerably in the last few years, but little has been known about their effect on the permanence of paper. Four types of fillers were used in the Bureau's work. They comprised clay, titanium dioxide pigments, zinc sulfide pigments, and calcium carbonate. The sizing agent was rosin soap prepared from rosin and soda ash, and was precipitated with papermaker's alum, aluminum sulfate. The fibrous materials covered the range of those commonly used in the fine printing papers.

Seventy-two experimental papers were manufactured in the Bureau's semicommercial mill. To determine the stability of the papers by natural aging would take years from the time they were manufactured. The Bureau believes that heating the papers at 100° C for 72 hours accelerates the normal slow deterioration caused by the impurities in papers, and that their comparative inherent permanence can be evaluated on the basis of the resistance to change in the heat treatment. Therefore, their stability was determined in this way.

The strength of the experimental papers decreased with increasing filler content, and was influenced by the amount, not the type, of filler. Since strength of paper is contributed principally by the fiber of which it is made, obviously when part of the volume is occupied by an inert or mineral filler there is a proportional decrease in the strength of the sheet. There was no pronounced difference in the relative effect of the nonalkaline fillers on the degree of sizing. Such fillers had less effect than calcium carbonate in reducing sizing values. Although the sizing values of the carbonate-filled papers were not high, the papers were sized sufficiently to be written on with ink and for ordinary printing processes.

Printing quality is dependent on opacity as much as on any other factor. The extent to which the passage of light

through paper is prevented is influenced by the light reflectance, or scattering effect, of the fillers. Papers containing titanium dioxide, zinc sulfide, or precipitated calcium carbonate pigments had the highest opacity, and in preliminary printing tests on a few of the papers, they gave the best printing results. Extensive printing tests to evaluate the printing quality of all the papers are to be made in a subsequent part of the investigation, and final opinion as to the relative value of the different fillers and other paper-making factors should await the results of the printings.

Rag and purified wood-pulp papers were more stable to the heat test than the sulfite-soda wood-pulp papers. Non-alkaline fillers had no apparent harmful influence on stability, and the calcium carbonate had a protective, or inhibiting, effect in aging. Rosin had little effect on stability, but acidity was an important factor in causing deterioration. The attack on the cellulose was increased as the amount of alum was increased, in either the unsized or the rosin-sized papers.

To make paper that is free from internal causes of deterioration will not, alone, insure permanence. The conditions under which the paper is stored and handled are equally important. The effect of external deteriorative agencies—light, temperature, humidity, acidic pollution of air—and recommendations as to storage conditions for prolonging the life of paper have been previously reported in this Bulletin.

CLASSIFICATION AND CHEMICAL GENETICS OF ORGANIC PLASTICS

A symposium on plastics was a feature of the semiannual meeting of the Electrochemical Society in Rochester, N. Y., on October 13. The introductory paper, delivered by Gordon M. Kline, chief of the organic plastics section of the Bureau, discussed the classification of plastics and reviewed the chemical reactions involved in their production.

Plastics, according to Dr. Kline, can be classified, on the basis of chemical source, into five principal groups: (1) synthetic resins; (2) synthetic "plastics"; (3) plastics from natural resins or bituminous materials; (4) cellulose derivatives; and (5) protein plastics. The first group may be subdivided into several chemical types of resins as follows: (a) phenolic-aldehydic, (b) amino-aldehydic, (c) hydroxy-carboxylic, (d) vinyl, (e) acrylic, (f) sty-

rene, and (g) indene resins. The first three types comprise the so-called condensation resins and the remaining four the polymerization resins.

The synthetic lastics are a group of materials which are synthesized from small molecular units by reactions similar to those used in resin chemistry to build up macromolecules, but which have properties resembling more nearly those of rubber than those usually associated with the resinous state. The term "rubber," however, has become definitely identified with a commercial product of well-established chemical constitution. The word "lastics" has therefore been suggested by Ellis as a generic name for the class of substances which possess rubber-like properties, irrespective of chemical structure. Various minimum limits of extensibility have been suggested for substances to be classified as synthetic lastics. However, the chief industrial application of a borderline material will probably govern its classification as a synthetic resin or synthetic lastic by chemists and engineers.

The present commercial synthetic lastics are subdivided into three groups: (a) the polymers of butadiene and its derivatives, (b) organic polysulfides, and (c) miscellaneous elastic substances produced from isobutylene, styrene, and polyvinyl chloride plasticized with tricresyl phosphate. These synthetic lastics fill a definite need in industry for materials with many rubber-like properties but superior to rubber in resistance to oils, gasoline, various solvents, ozone, atmospheric oxygen, and heat. It has been predicted that the next 10 years will see just as remarkable an extension of types and applications of these synthetic lastics as took place in the second decade of synthetic resin production between 1920 and 1930.

The group of natural resinous and bituminous plastics includes the natural resins, such as shellac and rosin, the bitumens, the resinous products derived from rubber by chlorination, hydrochlorination, and isomerization, and the plastic masses obtained by the chemical treatment of lignin. The cellulose derivatives are subclassified into (a) cellulose nitrate, (b) cellulose acetate, (c) cellulose mixed esters, and (d) cellulose ethers. The best-known plastics of the protein type are those made of casein, which is obtained from milk, and a commercial soy-bean meal molding composition containing a predominant percentage of phenol-formaldehyde resin. The use in plastic compositions

of zein obtained from corn, and alpha protein from soy beans is currently being investigated. Formaldehyde is used for the purpose of converting these proteins into hard and stable compounds.

The real romance of this industry rests in the ability of the active and excited younger set of molecules to get together and form by condensation or chain growth the heterogeneous population of giants which we know as plastics. It is also the research into the genetics of these organic compounds that has paid dividends by enabling the chemist to create at will synthetic materials having the hardness of stone, the transparency of glass, the elasticity of rubber, or the insulating quality of mica. Because their chemical heredity and molecular configuration largely determine the properties of the finished products, this exploration of the commercial plastics, in lieu of merely following the path of a census taker, has traced the development of these materials from their "single-cell" progenitors. In Doctor Kline's paper the outstanding characteristics and principal applications of each type of plastic were summarized and detailed references were given to tabulations of information on the properties, methods of fabrication, uses, trade names, and manufacturers and molders of plastics.

EFFECT OF PURIFICATION TREATMENTS ON COTTON AND RAYON

In certain studies relating to the use of cotton in the textile industry, treatment of the fiber is necessary in order to remove natural noncellulosic materials. A method for the removal of these impurities should be one that results in minimum damage to the fiber.

A study of the effects on cotton, cuprammonium rayon, and nitrocellulose rayon, of a typical procedure for the preparation of "standard cellulose" from cotton has just been completed by Ruby K. Worner and Ralph T. Mease of the Bureau's textile section. The effects of each step in the procedure (extraction with alcohol, ether, and a boiling 1-percent solution of sodium hydroxide), and of repetitions of this cycle of treatments, were measured by changes in weight, in the apparent fluidity of the solution of the product in cuprammonium, the copper number, and the alpha-cellulose content. All three kinds of fibers changed progressively with time of boiling in alkali. This was evident from the loss in weight of the

fibers, and the increase in the fluidity of their cuprammonium solution. Low copper numbers were obtained for all the fibers after the first extraction with alkali. Repeated treatments had no pronounced effect on the alpha-cellulose content of the cotton. Alcohol and ether extractions had no measurable effects other than the removal of soluble material during the first cycle of treatments. Thus, there appears to be no optimum time of treatment for the production of a "standard cellulose," and no indication that the properties would become constant with further treatment by this method.

Cotton was also treated with hydrochloric acid, and measurements were made of change in properties with time of treatment. The resulting products were characterized by increased reducing power and fluidity of their cuprammonium solution, and decreased alpha-cellulose content. They are not suitable for textile studies because the fiber structure is destroyed. The complete report of this work will be published as RP1146 in the November number of the Journal of Research.

CHEMICAL COMPOSITION OF THE "EXTRACT" PORTION ON A MIDCONTINENT LUBRICANT FRACTION

Two years ago results were reported of a joint investigation by the Bureau and the American Petroleum Institute, of the chemical composition of a "water-white" oil prepared from the lubricant fraction of a midcontinent crude petroleum. To obtain a more complete picture of the whole of the lubricant fraction, a similar investigation of the more soluble portion of the same lubricant fraction was recently completed by Beveridge J. Mair and Charles R. Willingham. As described in the Journal of Research for November (RP1143), the oil was first systematically distilled and separated into 144 fractions. This process produced a separation with respect to the average molecular weight. Five charges of these fractions were then prepared, and each charge of 500 to 700 g was separated by extraction in 55-ft columns into from 30 to 40 fractions. This process produced a separation with respect to the type of molecule. A number of properties have been determined on these fractions, each of which represents about 1/40,000 part of the original crude petroleum.

To obtain information as to the amount of aromatic hydrocarbons in

these fractions, a selected 15 of them were completely hydrogenated at temperatures from 230° to 250° C and pressures of hydrogen from 170 to 210 atm. Certain physical and chemical properties of the hydrogenated fractions were then determined, and are reported in RP1144 by Mair, Willingham, and Anton J. Streiff (November Journal). The sulfur, nitrogen, and oxygen were removed from the fractions and the fractions were converted completely to naphthenes by the hydrogenation process. There was no loss of carbon atoms.

Finally, a correlation has been made by Mair, Willingham, and Streiff of the data on the "extract" fractions, the hydrogenated fractions, the "water-white" oil fractions, and of the data available in the literature on synthetic hydrocarbons. The conclusions regarding the chemical composition of the lubricant fraction resulting from this correlation are set forth in the November Journal (RP1145). Excluding the "wax" and "asphaltic" portions, the oil contains: (1) about 60 percent of naphthenes with from 1 to 3 rings per molecule (a very small amount of material containing 4 naphthenic rings per molecule is probably present also); (2) about 15 percent of material with 1 aromatic ring and with from 1 to 3 naphthenic rings per molecule, together with a small amount of sulfur and oxygen compounds; (3) about 14 percent of material with 2 aromatic rings (linked through 2 common carbon atoms) and about 2 naphthenic rings per molecule, together with a small amount of sulfur and oxygen compounds; and (4) about 11 percent of material with more than 2 aromatic rings per molecule (each probably linked through 2 common carbon atoms) and 1 or 2 naphthenic rings per molecule, together with some sulfur, nitrogen, and oxygen compounds.

CESIUM DISCHARGE UNDER CONDITIONS OF NEARLY COMPLETE IONIZATION

RP1150 in the Journal of Research for November describes measurements made by Fred L. Mohler, of the spectral-intensity distribution of the continuous recombination spectrum, and used by him to measure electron concentration and electron temperature. Using radiation from a 1-mm capillary viewed end on, it has been possible to extend measurements to a current density of 300 amperes at pressures up to 17 mm. With increasing current the intensity reaches a flat maximum and this maximum increases as the square

of the pressure. Above 0.3-mm pressure, electron temperature is independent of pressure and increases linearly with current. The observations agree quantitatively with the theory that the cesium in the capillary is in temperature equilibrium at a temperature T_e and a pressure equal to the vapor pressure.

Electrical measurements of electron temperature and concentration have been made in a 5-mm tube with pressures ranging from 0.0045 to 0.3 mm. In this range temperature increases with decreasing pressure. The gas temperature is not in equilibrium with electron temperature, and electron concentration has a value which is higher than that corresponding to temperature equilibrium.

STRESSES IN A ROTATING PROPELLER BLADE

A knowledge of the natural frequencies and of the stresses caused by resonant vibrations at those frequencies is important in designing propeller blades. Metal blades of modern design are amply strong to withstand the static stresses from air loads and centrifugal force. Examination of propellers, the failure of which resulted in airplane accidents, has in every case indicated the presence of vibration before failure. Vibration may set up high alternating stresses at certain critical speeds at which the frequency of a periodic exciting force in the propeller-engine assembly or in the airflow coincides with a natural frequency of the propeller. Probably the most important natural frequencies are those for which the propeller vibrates flexurally like a beam of variable section. The determination of stresses in a nonrotating propeller vibrating in this manner was discussed in *J. Research NBS*, 14, 189 (February 1935) RP764. It was shown in this paper that the bending stresses in a propeller blade could be determined from strain measurements on the surface of the blade after the blade had been set into resonance with the desired flexural mode. Both the stresses so determined and the observed frequencies were found to agree with those calculated from the theory of beams of variable section.

The results of tests or calculations on nonrotating blades can be applied to propellers in flight only if the effect of rotation on the natural modes of vibration is clearly understood. In RP1148 (November Journal of Research) Walter Ramberg and Sam Levy discuss this

effect by extending the method of computing the natural modes of flexural vibration of nonrotating blades, described in RP764, to blades that rotate as in actual flight. The resulting equations were solved numerically for two aluminum-alloy propeller blades of typical design vibrating with the fundamental mode (with a node near the hub) and with the second harmonic mode (with one node near the tip and the other near the hub), and rotating at service speeds. Rotation was found to have a small effect on the maximum stress per unit tip deflection and was found to shift the maximum toward the hub. For engineering calculations it is probably sufficient to calculate the resulting stress in the rotating blade by superimposing the stress for no rotation on the steady stress due to air loads and to centrifugal force. A close and convenient approximation to the natural frequencies, which are needed to determine the critical speeds, was obtained from Lord Rayleigh's method by making use of the solutions for no rotation outlined in RP764. It is shown that both the stress distribution and the natural frequencies of a given propeller blade may be derived from those measured for a model blade by making use of two simple model rules developed by Theodorsen.

TESTS OF DOMESTIC GAS METERS

Ordinary gas meters have been regarded with distrust by the general public almost since they were first used. While there may have been some justification for this attitude at first, there is very little, if any, today. As a comparison, the water meters commonly used on residence service lines are required to register within ± 2 percent of the true amount over most of their range, while at very low rates may be incorrect by 10 percent or may not register at all. On the other hand, many jurisdictions require that gas meters shall be correct within ± 1 percent, and must register even the lowest rates of flow. Indeed, gas meters have been used to detect the presence of leaks in service piping! The public probably accepts water-meter statements more readily than those from gas meters, because water usually costs much less than gas, and whereas water can be seen coming from a faucet, so that one can visualize how much is used, gas is not visible as it issues from a stove burner.

To make more certain that, on the one hand, the user receives all the gas

he pays for on the basis of the meter indication, and on the other, that the gas company receives credit for all the gas the meter shows was delivered, the requirements of gas-meter testing are rather exacting. In the District of Columbia, for example, no gas meter can be placed in service unless it has been tested and passed by or under the personal supervision of the gas inspector of the Public Utilities Commission. This official noticed that occasionally the Commission's test disagreed with the test made by the gas company by a small amount (less than 1 percent). To reduce these occasional differences to a minimum, the Commission, together with the chairman of the American Gas Association's Committee on Meters and Metering, sought the Bureau's cooperation in studying possible sources of difference in gas-meter tests.

The first step in this study was to analyze and evaluate possible sources of errors. Next, tests were made on about 125 meters to compare different methods of using the index hands in making a test, and the relative abilities of several operators. Official tests of over 75 meters were observed and checked. Other tests were made of operator's abilities to stop a gas-meter test hand at a desired position and to set and read gas-meter prover scales. Some of the results of these tests may be summarized as follows:

1. There is no definite change in the condition or proof of a gas meter, as indicated by the successive tests made in this study.

2. On the average, the operators stopped a meter test hand within 0.012 inch of the starting point and rarely missed by as much as 0.01 inch.

3. The prover scales were set on zero at the start of a test to within less than 0.001 cu ft, and the final reading was made to within 0.01 cu ft—usually less than this.

4. In reporting meter proofs there appeared to be a tendency to give the "benefit of the doubt" on the slow side in border-line cases.

As a result of these tests, it was suggested that the positions of the meter provers and the meters be changed so that they might be observed by the operator with less possibility of error due to parallax; a new design of test hand for gas meters was offered.

The complete account of this study will be incorporated in the 1938 report of the Subcommittee on Meters and Metering, Distribution Committee, Technical Section of the American Gas Association.

STUDY OF SPECIFIC-GRAVITY INSTRUMENTS FOR FUEL GASES

At the request of and in cooperation with Committee D-3 of the American Society for Testing Materials, the Bureau has undertaken a study of the instruments available to the gas industry for determining, indicating, or recording the specific gravity of fuel gases. The tests will include determinations of accuracy, reproducibility, sensitivity, and various other operating characteristics. Approximately a dozen instruments of different types have already been received at the Bureau from a number of cooperating manufacturers, and the tests are expected to start shortly after December 1, 1938. The committee is anxious to obtain full representation of all manufacturers, but no additions to the list of instruments will be considered after the tests are under way.

SIMPLIFICATION OF SIZES OF STOCK FOLDING BOXES

Simplified Practice Recommendation R172-38, Stock Folding Boxes for Garments and Dry Cleaning became effective September 1, 1938.

This recommendation, which is based on a survey of production and sales to determine the sizes most frequently used, lists dimensions of boxes and thicknesses of board for stock folding boxes (automatic and lock-corner types) used by garment and specialty stores, as well as dry cleaning and tailoring establishments. The sponsors believe that through the establishment of this simplification program, the users who buy stock boxes in relatively small quantities should be able to fill their needs more economically, since, under the plan, producers will carry in stock at all times the selected standard sizes, thus obviating the necessity for special manufacture.

A standing committee, composed of representatives of the industry and allied interests, will have charge of this recommendation with a view to maintaining it abreast of current practice. The members of this committee as well as the acceptors of the recommendation will be listed in the printed issue, which will include, also, a brief statement of the development of the project.

Until the printed booklet is available, free mimeographed copies of the recommendation may be obtained from the Division of Simplified Practice, National Bureau of Standards, Washington, D. C.

NEW AND REVISED PUBLICATIONS ISSUED DURING OCTOBER 1938

Journal of Research²

Journal of Research of the National Bureau of Standards, volume 21, number 4, October 1938 (RP1137 to RP1142, inclusive). Price 30 cents. Annual subscription, 12 issues, \$3.50.

Research Papers²

(Reprints from the July and August 1938 Journal of Research)

RP1111. Measurement of supervoltage X-rays with the free-air ionization chamber. Lauriston S. Taylor, George Singer, and Arvid L. Charlton. Price, 10 cents.

RP1112. Preparation and application of chromous solutions for the absorption of oxygen in volumetric gas analysis. Joseph R. Branham. Price, 5 cents.

RP1114. Hydrogen-reduction method for the determination of oxygen in steel. John G. Thompson and Vernon C. F. Holm. Price, 5 cents.

RP1116. Determination of arsenic, antimony, and tin in lead-, tin-, and copper-base alloys. John A. Scherrer. Price, 5 cents.

RP1117. Improved method for determination of aluminum in certain non-ferrous materials by use of ammonium aurintricarboxylate. John A. Scherrer and William D. Mogerman. Price, 5 cents.

RP1118. Preparation of ammonium aurintricarboxylate. John A. Scherrer and W. Harold Smith. Price, 5 cents.

RP1119. Combination of hydrochloric acid and sodium hydroxide with hide, tendon, and bone collagen. John Beck, Jr. Price, 5 cents.

RP1120. Determination of boron in steel and cast iron. John L. Hague and Harry A. Bright. Price, 5 cents.

RP1121. Studies of heat of solution of calcium and magnesium oxides and hydroxides. Kenneth Taylor and Lansing S. Wells. Price, 5 cents.

RP1122. Separation of isopropylbenzene from a midcontinent petroleum by adsorption with silica gel, and distilla-

tion acetic acid. Joseph D. White and Frank W. Rose, Jr. Price, 5 cents.

RP1123. Separation, by distillation with acetic acid, of the aromatic hydrocarbons from the fraction of a mid-continent petroleum boiling between 154° and 162° C. Frank W. Rose, Jr., and Joseph D. White. Price, 5 cents.

RP1124. Extension and revision of the arc spectrum of silicon. Carl C. Kiess. Price, 5 cents.

RP1125. Preliminary lists of terms for the arc and spark spectra of tungsten. Donald D. Laun. Price, 5 cents.

RP1126. Electrolytic resistors for direct-current applications in measuring temperatures. D. Norman Craig. Price, 10 cents.

RP1127. Effect of glass content upon the heat of hydration of Portland cement. William Lerch. Price 10 cents.

RP1128. Accelerated aging of leather in the oxygen bomb at 100° C. Joseph R. Kanagy. Price 5 cents.

Handbooks²

H23. Radium protection. (Supersedes H18.) Price 10 cents.

Simplified Practice Recommendations²

R32-38. Concrete building units. (Supersedes R32-32.) Price 5 cents.

R37-38. Commercial forms (Invoice, purchase order, and inquiry). (Supersedes R37-28.) Price 10 cents.

Building Materials and Structures²

BMS3. Suitability of fiber insulating lath as a plaster base. Lansing S. Wells and D. C. Smith. Price 10 cents.

Technical News Bulletin²

Technical News Bulletin 258, October 1938. Price 5 cents. Annual subscription, 50 cents.

MIMEOGRAPHED MATERIAL

Letter Circulars

Letter Circulars are prepared to answer specific inquiries addressed to the National Bureau of Standards, and are sent only on request to persons having definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.

LC532. Rubber: Lists of publications by members of the staff of the Na-

² Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington, D. C. Subscription to Technical News Bulletin, 50 cents per year; Journal of Research, \$3.50 per year (United States and its possessions, and Canada, Colombia, Cuba, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Newfoundland (including Labrador), Panama, and Venezuela); other countries, 70 cents and \$4.50, respectively.

tional Bureau of Standards. (Supersedes LC178.)

LC533. Sources of information (books) on the properties of metals and alloys. (Supersedes LC479.)

RECENT BUREAU ARTICLES APPEARING IN OUTSIDE PUBLICATIONS^a

Recent developments related to underground corrosion. Kirk H. Logan. Oil and Gas J. (Tulsa, Okla.) **37**, No. 19, 212 (September 22, 1938).

Making soil-corrosion survey by using electrolytic test. I. A. Denison. Oil and Gas J. **37**, No. 19, 96 (September 22, 1938).

The free energy of the producer-gas reaction and the "zero-point" entropy of graphite. F. D. Rossini. J. Chem. Physics (175 Fifth Ave., New York, N. Y.) **6**, 569 (September 1938).

Building codes combine facts and judgment. H. L. Dryden. Ind. Standardization (29 West 39th St., New York, N. Y.) **9**, 124 (May 1938).

The crinkling strength and the bending strength of round aircraft tubing. William R. Osgood. Report 632 (Na-

^a These publications are not obtainable from the Government unless otherwise stated. Requests should be sent direct to the publishers.

tional Advisory Committee for Aeronautics, Washington, D. C.) (September 1938) (Obtainable from Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents a copy.)

Notes on selection of cellulose acetate film for record purposes. B. W. Scribner, J. Documentary Reproduction (Am. Library Assn., 520 North Michigan Ave., Chicago, Ill.) **1**, No. 2, 210 (Spring 1938).

Plastics as structural materials for aircraft. Gordon M. Kline. J. Aero. Sci. (20th and Northampton Sts., Easton, Pa.) **5**, 391 (August 1938), and Modern Plastics (425 Fourth Ave., New York, N. Y.) **15**, No. 6, 35 (August 1938) and **16**, No. 1, 44 (September 1938).

A method of preparation of metallographic specimens. George A. Ellinger and Joseph S. Acken. Preprint 22 (Am. Soc. Testing Materials, 260 South Broad St., Philadelphia, Pa.), (September 1938).

Critical cooling rates. T. G. Digges. Metallurgist (28 Essex St., Strand, London, W.C.2, England) **145** (August 26, 1938).

Potash in the glass industry. A. N. Finn. Ind. and Engrg. Chem. (706 Mills Bldg., Washington, D. C.), **30**, 891, (August 1938).

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